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TO

SPECIAL SCIENTIFIC MEETINGS

1946

HERRING PROBLEMS

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INTRODUCTION

BY

K. A. ANDERSSON

At the Meeting of the International Council for the Exploration of the Sea, held in Copenhagen in 1945, it was decided that a special Meeting on Herring Problems should be held at the present Council Meeting, and I was honoured by being appointed Convenor of this Meeting on Herring.

Herring is, as we know, the most important species of fish in Europe, and it was therefore a matter of course that it should be given the first place on the Council's programme. Herring fishing has always been of immense consequence for the nations of western Europe, but the occurrence of the herring has varied enormously during the centuries, and this has periodically resulted in very scanty catches and has adversely affected the economic life of the fishing population, in some cases leading to complete ruin.

The fluctuations of the herring have often given the fishing population the impression of capriciousness. Herring became a fish surrounded by mystery and, as we know, the most peculiar theories were advanced to explain the variable appearance of the herring.

When international exploration of the sea began, our knowledge of the conditions of life of the herring was still almost as imperfect as before, even if some scientists had made many important observations on the life of the herring.

When the Swedish scientists OTTO PETTERSSON and GUSTAF EKMAN nearly 50 years ago took the initiative of constituting our international organisation for the exploration of the sea, I am sure that they were primarily thinking of the herring.

They had put forward the great and stimulating idea that the migrations of the herring, which were regarded as the cause of the great fluctuations in the herring fishery, must probably be due to hydrographical conditions or to the environment and the changes in it. OTTO PETTERSSON and GUSTAF EKMAN were of the opinion that international co-operation was essential for the investigation of the causes of the migrations of the herring or

of its variable occurrence. It was from these trains of thought that they took their initiative, And it may also be said, I should think, that the study of the conditions of life of the herring alone would have been sufficient to justify such an organisation as the International Council for the Exploration of the Sea.

Here I will not embark upon any account of the results reached by the international exploration of the sea in regard to herring. But I should like to draw your attention to some of them.

With the aid of age determination, our President, Professor HJORT, in his epoch-making work "Fluctuations in the Great Fisheries", showed that the different year-classes were subject to great fluctuations in numerical strength and that this circumstance was the cause of great variations in herring fishing. This represents a great advance for science and one which is of much significance for the fishery. This discovery has also created the possibility of predicting how the fishing will be, in certain cases.

But the fluctuations in the strength of the year-classes must have some cause, and HJORT advanced the idea that the cause might be found in the supply of plankton during the larval stage of the herring. Subsequent Norwegian investigations have also shown that the young herring larvae pass through two very critical periods when the lack of suitable food may result in the wholesale death of the herring larvae. It has also been possible to establish that a high water temperature is in some cases favourable to the initiation of rich year-classes. There are likely to be other environmental conditions, too, which are of consequence for the occurrence of rich and poor year-classes.

Age determination has also provided a means of studying the individual rate of growth of the herring. It has been possible to establish that the growth of the herring is very much influenced by the surrounding milieu, the temperature of the water and the supply of food, so that the growth-rate becomes less in cases of low temperature or shortage of food.

The question of the capacity of the herring to form different "races", or forms, or "populations", with certain anatomical and biological dissimilarities, has been the object of comprehensive investigations, which have led to important results, even if complete agreement perhaps does not exist among all investigators in regard to these results. A factor that is of significance here is to what degree different environments can produce dissimilarities between different "populations". The varying hydrographical conditions prevailing in the spawning places may perhaps be the cause of the origin of different "populations". Investigations carried out in Denmark and Norway point in this direction. For a closer study of this problem the meeting of Herring Experts held at Charlottenlund in October 1945 made the following two recommendations:

> "Hydrographical investigations should be undertaken on the spawning grounds of the herring at the time of the spawning season. If possible such investigations should be carried out in the form of continuous observations during the spawning period"

and

"Experiments regarding the hatching of herring spawn and the rearing of herring fry should be promoted in order to study how far race characters are dependent upon temperature and other physical conditions and at what stage of development this dependency asserts itself. Similar investigations regarding the sprat would be desirable."

'But the great question that OTTO PETTERSSON and GUSTAF EKMAN put forward as a primary aim for the international marine exploration in regard to herring, namely the hydrographical factors as the cause of the migrations of the herring, particularly in the North Sea-Skagerak area, must still be regarded as unsolved. The question, as we know, is this, whether during later decades such changes have taken place in the hydrographical conditions within the area mentioned as can have caused the great fluctuations in the occurrence of the herring in the Skagerak and the Kattegat that have arisen during the last 50 years. In order to try to solve this problem the above-mentioned meeting of Herring Experts made the recommendation in October 1945 that the hydrographical observations from the Kattegat and the Skagerak collected in Denmark and Sweden during the last 50 years should be worked up as soon as possible, and that this work should also include observations on the water exchange between the North Sea, the Skagerak and the Kattegat, provided such observations are available.

When this work is complete, it is to be hoped that the problem of the influence of the hydrographical conditions on the occurrence of the herring will have come nearer solution.

THE HERRING OF THE NORTH-WESTERN NORTH SEA

BY

HENRY WOOD

The Summer Herring Fishery extends from May, sometimes April, until September. During this period the distribution of the shoals is variable and unequal, but from a survey of catches there is strong evidence of a fairly definite flow and ebb in the density of the population on certain grounds in a definite chronological sequence.

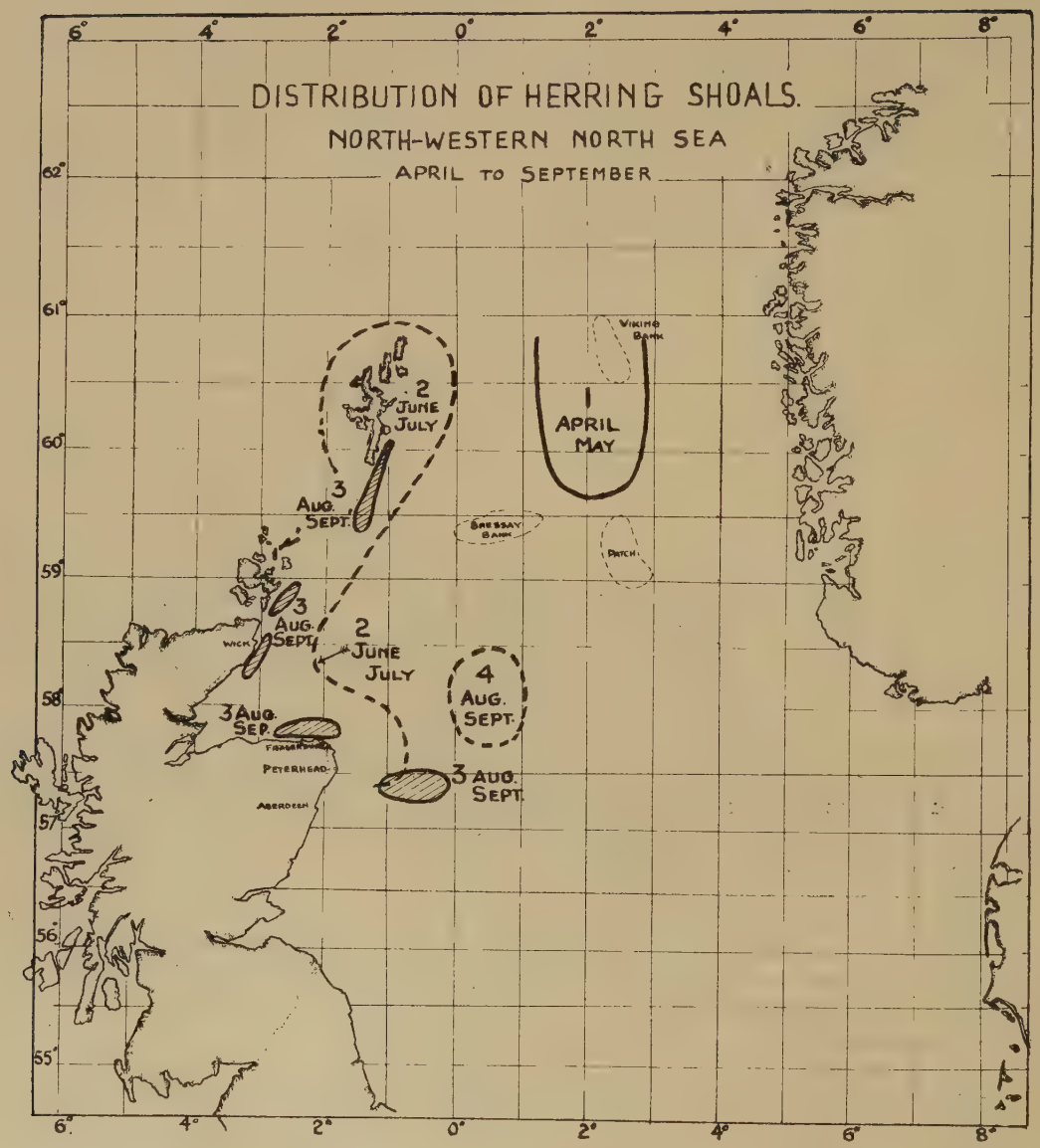
I. The earliest concentration exploited commercially is in the waters between Shetland and Norway, extending from Bressay Bank to the Patch and northwards, at least to beyond the Viking Bank. Here shoals are normally abundant in April and May, although in May the centre of greatest density would appear to be nearer the Shetland coast.

II. From early in May until about the middle of July herring shoals are distributed around the Shetland Islands, and from Shetland down to the latitude of Peterhead or Aberdeen, and good catches are obtainable from coastal waters to distances of 30 or 40 miles from land. The more distant grounds are generally the more productive in July.

III. About mid July there is often evidence of a decrease in the density of the herring population off the Scottish N. E. grounds and generally drifters have to go farther to sea to get good catches. There is in fact a splitting up of the herring population; non-spawners, including spring spawners leave the drift net grounds, while late in July the August-September spawners begin to move towards their spawning grounds near the coast.

IV. In August the resulting two new concentrations become apparent, the autumn spawners appearing on the grounds nearer the coast and a very large concentration of herring, not yet ripe for spawning, on and in the neighbourhood of the Fladen Ground.

Our purpose is to analyse briefly samples of herring from each of these concentrations to see if they belong to the same stock or are representatives of different groups or types of herring.



IMMATURE HERRING

Immature herring occur in all areas and fortunately their identity can be established wherever they occur in the Northern and North-Western North Sea. It will simplify matters, therefore, if we deal with those first and eliminate them from the material to be discussed later.

In the Scottish "Race" investigations the counts of total number of vertebrae and keeled scales have been used for the identification of different herring types. The two characters, however, form independent criteria for this purpose and for the sake of brevity only the counts of vertebrae are given here in Table I.

Table I.

Vert. S. of Immature Herring

Year	55	56	57	58	59	Mean	Fish Examined
			Viking-Patch-Bressay Bank (Drift Nets)				
1931	-	18.3	64.3	17.4	-	56.99	115
1934	0.3	12.0	67.2	19.5	1.0	57.09	308
1935	1.5	22.7	62.1	12.1	1.5	56.90	66
1936	1.1	15.3	63.6	19.4	0.7	57.03	439
1937	0.8	7.8	60.5	29.5	1.5	57.23	129
1938	-	19.2	57.7	23.1	-	57.04	78
1939	-	15.6	57.8	24.4	2.2	57.13	45
			Shetland (Drift Nets)				
1934	0.3	12.7	63.4	22.8	0.9	57.11	347
1935	1.1	17.2	65.6	15.0	1.1	56.98	92
1936	0.3	15.7	62.0	21.0	0.9	57.07	324
1937	0.9	11.0	62.4	22.9	2.8	57.16	109
1938	-	8.9	67.9	19.6	3.6	57.18	56
			Drift Net Grounds: Scottish North-east Coast (Drift Nets)				
1934	8.9	49.1	40.2	1.8	-	56.35	112
1935	4.0	39.6	48.3	7.7	0.4	56.61	455
1936	1.1	24.0	55.9	18.4	0.6	56.93	179
1937	-	20.4	57.1	20.6	1.9	57.04	622
1938	3.1	40.5	51.9	4.6	-	56.58	590
1939	3.7	38.7	52.4	4.8	0.4	56.59	483
			Fladen Ground (Herring Trawl)				
1934	1.0	17.2	60.6	21.2	-	57.02	99
1935	1.8	19.3	52.6	26.3	-	57.04	57
1936	-	17.9	63.1	19.0	-	57.01	84
1937	2.3	18.4	54.0	21.8	3.4	57.06	87
1939	2.5	12.5	67.5	17.5	-	57.00	40

From the data given in Table I one can say with complete assurance that the immature herring of the Viking Bank-Shetland area and of the Fladen Ground belong exclusively or almost exclusively to a spring spawning stock. Those caught on the drift net grounds off the east and north-east coasts of Scotland are, on the other hand, variable in composition, ranging from almost pure autumn spawners, as in 1934, through varying mixtures of spring and autumn spawners, to almost pure spring spawners as in 1937.

It is worthy of note that many of the immatures caught on the Shetland grounds, and in 1937 on the grounds off the N.E. of Scotland, showed distinctive scale patterns and growth features typical of the young herring of northern Norway.

Age Composition.

Tables II, III, IV and V give the age composition of adult herring (a) from the Viking Bank and Patch area, (b) from the drift net grounds off the N. E. of Scotland in June and July, (c) spawners from the Scottish autumn spawning grounds in August and September, and (d) spents from the Fladen from September to December.

Table II.

Age Composition of Adult Herring

Viking Bank, Bressay Bank and Patch: April and May.

Year	Winter Rings								Fish Examined
	3	4	5	6	7	8	9	10+	
1932	No Records.								
1933	6.5	40.0	26.0	10.1	5.4	7.3	3.7	0.9	535
1934	14.2	13.4	44.2	15.4	4.3	2.2	2.6	3.7	507
1935	5.4	31.2	14.3	33.5	9.3	2.4	1.8	2.1	847
1936	16.8	31.8	28.3	10.2	10.2	1.4	0.7	0.7	764
1937	3.9	28.5	34.6	17.3	3.9	8.1	2.6	1.0	382
1938	3.6	12.5	36.1	22.6	9.8	3.9	8.9	2.6	305
1939	1.2	6.1	17.1	44.1	20.6	2.3	2.3	6.4	345

Table III.

Age Composition of Herring from Drift Net Grounds off Scottish North-East Coast (Imms. and 2-ringers omitted): June/July

Year	Winter Rings								Fish Examined
	3	4	5	6	7	8	9	10+	
1932	67.1	21.5	6.3	2.1	1.8	0.6	0.3	0.2	3,065
1933	52.6	32.0	10.3	2.7	1.4	0.8	0.2	0.1	1,884
1934	29.1	50.2	13.4	4.5	1.6	0.7	0.4	0.2	2,818
1935	62.6	13.5	16.6	4.7	1.7	0.6	0.1	0.1	2,632
1936	41.6	30.5	6.7	10.6	8.2	1.6	0.6	0.2	1,507
1937	24.6	38.4	22.0	4.5	5.0	4.1	1.2	0.1	1,178
1938	48.4	16.8	18.7	7.4	2.2	4.4	1.2	0.9	1,761
1939	39.8	45.2	7.8	4.6	1.7	0.5	0.2	0.2	1,519

Table IV.

Age Composition of Spawners.
Scottish N.E. Coast: August and September.

Year	Winter Rings									Fish Examined
	2	3	4	5	6	7	8	9	10+	
1932	1.8	60.8	9.2	9.2	5.0	3.0	5.9	4.2	0.9	356
1933	4.7	6.8	52.6	9.4	6.3	7.4	5.3	5.2	2.4	903
1934	2.9	6.6	10.4	58.0	8.9	7.1	3.1	1.5	1.5	520
1935	6.8	15.7	8.0	10.1	43.5	5.3	4.6	3.7	2.4	678
1936	0.3	6.6	10.4	9.0	10.7	42.6	8.0	6.9	5.5	289
1937	0.0	0.6	8.0	15.3	4.6	12.5	47.2	5.1	6.8	176
1938	2.1	23.4	2.1	17.0	10.6	10.6	2.1	25.5	6.4	162
1939	26.4	31.0	20.8	1.9	6.5	2.3	1.4	3.2	6.5	354

Table V.

Age Composition of Spents.
Fladen Ground September to December

Year	Winter Rings									Fish Examined
	2	3	4	5	6	7	8	9	10+	
1932	5.1	53.9	10.3	12.8	7.7	2.6	7.7	-	-	40
1933	2.4	10.9	55.2	9.0	4.6	6.5	2.7	3.0	5.7	365
1934	1.0	8.9	12.3	51.5	10.6	5.9	3.7	3.4	2.7	595
1935	1.2	5.6	8.0	7.8	43.3	12.3	6.2	5.2	10.5	498
1936	-	6.1	9.8	6.1	8.5	62.2	2.4	0.0	4.9	606
1937	0.4	1.6	14.0	9.0	6.2	12.1	43.2	5.8	7.8	253
1938	1.2	14.5	2.9	10.0	13.9	7.0	9.8	34.0	6.8	499
1939	10.1	9.3	35.7	0.8	5.4	6.2	3.9	3.1	25.6	128

Comparison of the age composition tables provides some interesting surprises. For example, it is clear from Table III that on the drift net grounds off the Scottish N. E. coast in June and July the adult or maturing herring are predominantly 3- and 4-ringers and that year classes having more than 5 winter rings on the scales are relatively few. On the other hand, it is seen from Table IV that the age composition of the spawners on the same or adjacent grounds in August and September can be and frequently is quite different from that of the earlier shoals. On the other hand, it is clear that the age groups which predominate amongst the spawners (Table IV) are also important amongst the adult herring caught in the waters between Shetland and Norway in April and May (Table II). As there is rarely evidence of an increase but rather a decrease in the density of the herring population on the Scottish drift net grounds in July and August, it is inferred that the change in the age composition is due in part to withdrawal from the area of important components of the population.

It will be seen by comparison of Table IV and Table V that there is almost complete agreement between the ages of the spawners on the drift net grounds and the spent herring caught by trawlers on the Fladen Ground between September and December.

Age Composition of Maturing Herring of the Fladen Ground in August and September.

Three well-defined groups of herring occur on the Fladen Ground in autumn. It has already been shown that the immature fish are derived almost exclusively from spring spawning stock. The same is true of the majority of the herring caught on the Fladen Ground in autumn at maturity stages II and III. We have already seen that the spents are identical in age composition with the coastal spawners. We are left, therefore, with the herring at maturity stages IV and V which predominate throughout August and the greater part of September. Their age composition is given in Table VI.

Table VI. Age Composition of Herring at Maturities IV and V Fladen Ground: August/September.

Year	Winter Rings									Fish Examined
	2	3	4	5	6	7	8	9	10+	
1932	0.3	12.5	18.1	14.9	12.5	17.0	9.7	11.1	3.8	288
1933	0.3	4.0	26.9	23.1	11.6	9.0	10.8	7.3	7.0	398
1934	3.4	10.5	11.7	34.0	16.0	11.3	4.9	4.7	3.6	506
1935	-	4.1	12.5	12.5	29.2	17.6	10.2	4.9	9.0	391
1936	-	2.5	9.4	13.6	19.9	20.3	19.2	7.7	7.3	286
1937	0.3	0.7	8.5	14.2	16.6	19.3	15.6	14.9	9.8	295
1938	-	0.4	2.2	7.5	18.1	14.5	17.6	18.5	21.1	227
1939	-	-	12.5	2.1	14.6	27.1	16.7	6.3	20.8	48

Here we have a group differing appreciably from all the others so far considered with respect to age. Fish with 2 or 3 winter rings are unimportant, the outstanding age classes being those having from 4 to 10 winter rings on their scales.

These herring have left the Fladen Ground completely by the end of September. They are not encountered on any Scottish Fishing grounds in late autumn or in winter, either as spawners or as spents, and of course the Fladen Ground is not a spawning area.

It is proposed to attempt to identify the herring which leave the drift net grounds in July and the herring caught at maturity stages IV and V on the Fladen Ground in August and September.

"Race"Characters:

Counts of vertebrae and keeled scales are given in Tables VII to X for (1) ripe or newly spent herring caught on the spawning grounds off the east and north-east coasts of Scotland, (2) spents caught by trawl on the Fladen Ground from August to December, (3) samples of maturing herring caught on the drift net grounds between May and August, but for the most part in June and early July, and (4) herring at maturity stages IV and V caught on the Fladen Ground from the end of July until towards the end of September. The very few herring caught at these maturities after September are spring spawners.

It has already been seen from Tables IV and V that there is complete agreement with respect to age composition between the spawners caught in August and September on the drift net grounds and the spents caught on the Fladen from August to December. By comparing Tables VII and VIII it will be seen that there is equally good agreement with respect to counts of vertebrae and K_2, leaving no doubt whatsoever that both belong to that group of type which spawns near the Scottish east and north-east coasts in August and September.

There is, however, much greater difficulty in establishing the identity of those adult herring which are present sometimes in very large numbers on the drift net ground in June and July but which are absent from the spawning shoals in August and September, and of those herring caught at maturity stages IV and V on the Fladen Ground in August and September.

Although they differ widely from each other with respect to age, it will be seen by reference to Tables IX and X that both are characterised by the relatively low vertebral counts which typify North Sea autumn spawners generally. In one respect, however, they show an interesting difference from the herring which spawn in autumn in Scottish waters, in that they have the K_2 slightly but consistently higher.

Discrimination by Differences of Means.

The usual test for the differences of means of two samples is the "t" test. In this test the standard deviation of the difference of means is

V E R T. S.

Table VII.

Spawners - Stages VI and VII: Scottish N.E. Coast (Drift Net Grounds)

Date	54	55	56	57	58	59	60	Mean	S
Aug. 1932	-	4.2	48.6	43.4	3.3	-	0.5	56.48	.05
Aug. 1934	-	4.2	52.3	43.0	0.4	-	-	56.40	.03
Aug. 1935	0.3	2.2	52.4	43.5	1.4	-	0.3	56.45	.04
Aug./Sep. 1936	-	3.2	54.2	38.8	3.5	0.3	-	56.44	.05
Aug. 1937	-	3.4	49.4	43.1	4.0	-	-	56.48	.04
Aug. 1938	-	4.3	48.1	46.9	0.8	-	-	56.44	.05
Aug. 1939	0.3	4.8	48.0	42.7	4.2	-	-	56.46	.04

Table VIII.

"Race" Characters of Spents from Fladen Ground

Date	54	55	56	57	58	59	60	Mean	S
Aug./Sep. 1932 [+)]	-	2.5	57.5	35.0	5.0	-	-	56.42	.10
Aug./Oct. 1933	-	3.0	53.3	39.6	4.1	-	-	56.45	.03
Aug./Dec. 1934	-	4.0	50.9	41.7	3.2	0.2	-	56.45	.03
Sep./Dec. 1935	-	6.0	49.6	40.6	3.6	-	0.2	56.43	.03
Aug./Nov. 1936	-	5.0	55.4	37.1	2.3	0.2	-	56.37	.03
Aug./Oct. 1937	-	3.2	54.5	40.3	1.6	0.4	-	56.42	.04
Sep./Nov. 1938	-	3.0	53.9	39.5	3.6	-	-	56.44	.03
Aug./Oct. 1939 [++)]	-	7.9	51.2	37.8	3.2	-	-	56.36	.06

[+)] Only 40 fish. [++)] Only 128 fish.

Table IX.

Maturing Herring - Stages II to V: Scottish N.E. Coast (Drift Net Grounds)

Date	54	55	56	57	58	59	60	Mean	S
May 9-Aug. 14, 1934	0.3	3.6	44.8	47.8	3.4	0.2	-	56.51	0.2
May 22-July 9, 1935	-	5.5	48.6	42.2	3.5	0.1	-	56.44	0.2
June 2-Aug. 12, 1936	0.1	3.3	48.7	45.1	2.5	0.2	-	56.47	0.2
May 18-July 20, 1937	-	3.7	45.0	47.0	4.4	-	-	56.52	0.2
May 31-Aug. 16, 1938	0.1	3.3	46.7	45.2	4.5	0.1	-	56.48	0.2
June 2-July 11, 1939	-	3.9	42.4	50.3	3.5	-	-	56.53	0.3

K_2

Table VII.

Spawners - Stages VI and VII: Scottish N.E. Coast (Drift Net Grounds)

Date	11	12	13	14	15	16	17	18	19	20	Mean	S
1932	-	1.0	4.3	32.6	45.9	10.5	5.3	0.5	-	-	14.78	.07
1934	-	-	3.5	29.8	45.2	17.5	4.0	-	-	-	14.89	.06
1935	-	0.3	3.7	29.5	43.1	19.8	2.8	0.6	0.3	-	14.91	.05
1936	-	-	3.2	27.6	44.8	19.6	4.2	0.3	0.3	-	14.92	.05
1937	-	-	2.3	32.8	42.5	19.0	2.9	0.6	-	-	14.89	.07
1938	-	-	5.6	30.4	45.3	14.9	3.1	-	0.6	-	14.82	.07
1939	-	-	2.8	33.1	41.8	17.5	4.2	0.3	0.3	-	14.89	.05

Table VIII.

"Race" Characters of Spents from Fladen Ground

Date	11	12	13	14	15	16	17	18	19	20	Mean	S
1932+)	-	-	-	41.0	46.2	12.8	-	-	-	-	14.72	.10
1933	-	0.6	5.0	32.0	43.8	15.4	3.0	0.3	-	-	14.79	.05
1934	-	0.5	5.3	27.3	45.3	17.4	2.9	0.9	0.5	-	14.88	.04
1935	0.2	0.4	5.4	28.9	43.8	15.9	4.5	0.8	-	-	14.86	.05
1936	0.2	0.2	3.2	31.7	44.0	16.0	3.8	0.7	0.3	-	14.88	.04
1937	-	-	4.4	27.8	47.6	12.5	5.2	1.6	0.4	0.4	14.95	.07
1938	-	-	3.6	26.1	47.6	17.7	4.2	0.4	0.4	-	14.95	.04
1939++)	-	-	7.0	21.9	48.4	18.0	3.1	1.6	-	-	14.93	.09

+) Only 40 fish. ++) Only 128 fish.

Table IX.

Maturing Herring - Stages II to V: Scottish N.E. Coast (Drift Net Grounds)

Date	11	12	13	14	15	16	17	18	19	20	Mean	S
1934	-	0.1	2.2	25.5	46.7	21.5	3.7	0.3	0.1	-	15.0	.03
1935	-	-	2.6	23.1	48.4	21.4	4.3	0.1	0.1	-	15.03	.03
1936	-	0.2	2.5	23.9	46.9	21.5	4.6	0.5	-	-	15.03	.03
1937	-	-	3.9	21.9	47.0	20.9	5.2	0.9	0.1	-	15.05	.04
1938	-	-	2.7	23.4	48.3	21.4	4.0	0.2	-	-	15.01	.02
1939	-	-	1.8	20.8	49.5	23.0	4.6	0.2	-	-	15.08	.04

VERT. S.

Table X. "Race" Characters of Herring at Maturities IV-V Fladen Ground

Date		54	55	56	57	58	59	60	Mean	S
July-Sep.	1932	-	2.1	48.4	44.6	4.6	0.3	-	56.53	.04
"	1933	-	5.4	48.3	41.7	4.3	0.3	-	56.45	.04
"	1934	0.2	4.5	46.3	46.1	2.9	-	-	56.47	.03
"	1935	-	1.3	51.0	43.5	4.3	-	-	56.51	.03
"	1936	-	5.6	41.8	48.4	4.2	-	-	56.51	.04
"	1937	-	2.2	47.8	47.4	2.6	-	-	56.50	.04
"	1938	-	5.0	52.2	38.7	3.6	0.5	-	56.41	.04
"	1939[+)]	-	-	53.2	44.7	2.1	-	-	56.47	.06

[+)] Only 47 fish.

found; the actual observed difference of the two means is then divided by this standard deviation: The resulting ratio, "Students Ratio", is called "t".

According to A.C.Aitken, Professor of Mathematics at Edinburgh University, when dealing with large samples, 200 fish or over as in the present case, a good working rule is as follows: the chance of "t" being equal to or greater than 2 is about 1 in 20 under pure randomness; the chance of "t" being greater than 2.6 is about 1 in 100. Thus when "t" exceeds 2, one begins to think in large samples that ordinary randomness is not enough to explain the difference in means, but that there is some systematic difference, some essential difference of type, present.

The test has been applied to differences in the means of K_2 of samples of autumn spawners caught on the drift net grounds (except in 1933 when spents from the Fladen Ground had to be used), and of samples of herring at maturity stages IV and V caught on the Fladen Ground in August and September. The results are given in Table XI.

Table XI. Analysis of K_2 Means

Year	Fladen Ground Mats. IV/V		Scottish Autumn Spawners		$M_1 - M_2$	Standard error of $M_1 - M_2$	"t"
	M_1	S_1	M_2	S_2			
1933	15.09	.05	14.79	.05	.30	.071	4.2
1934	15.10	.04	14.89	.06	.21	.072	2.9
1935	14.96	.045	14.91	.05	.05	.068	0.7
1936	15.09	.05	14.92	.055	.17	.074	2.35
1937	15.00	.05	14.89	.07	.11	.086	1.3
1938	15.11	.06	14.82	.07	.29	.092	3.15

K_2

Table X. "Race" Characters of Herring at Maturities IV-V Fladen Ground

Date	11	12	13	14	15	16	17	18	19	20	Mean	S
1932	-	-	2.8	23.1	50.0	20.2	3.2	0.7	-	-	15.00	.05
1933	-	-	2.0	24.7	43.0	24.7	4.5	0.8	0.3	-	15.09	.05
1934	-	-	2.2	19.6	52.0	19.6	5.6	0.4	0.6	-	15.10	.04
1935	-	0.2	3.5	28.6	41.4	21.5	3.9	0.7	0.2	-	14.96	.05
1936	-	-	2.8	21.9	44.6	25.4	4.2	1.0	-	-	15.09	.05
1937	-	-	1.9	25.1	50.2	17.2	4.9	0.7	-	-	15.00	.05
1938	-	0.4	0.9	21.3	49.8	21.3	4.9	1.3	-	-	15.11	.05
1939 +)	-	-	6.3	18.7	45.8	25.0	2.1	2.1	-	-	14.99	.1

+) Only 47 fish.

The results do not give a clear-cut discrimination in every case, but in four out of the six pairs of samples they show that the differences in the mean K_2 are such as are extremely unlikely to arise from mere randomness, and that the indications are that we have a type which is closely allied to the Scottish autumn spawners but which spawns later in the autumn and which in most cases can be distinguished from them by counts of the K_2. Many of the herring caught on the Scottish drift net grounds in June and July obviously belong to the same type, but in this case it is difficult to obtain samples free from admixture of spring spawners and Scottish autumn spawners.

The question now arises as to where and when these herring spawn.

Middle North Sea Herring.

From time to time odd samples of herring have been obtained from the middle North Sea between the latitudes of Berwick and the Spurn, and counts of vertebrae and K_2 bear a very close resemblance to those of the herring discussed above. The results are given in Table XII.

The samples detailed in Table XII have the number of vertebrae typical of North Sea autumn spawners. The K_2, however, are slightly but significantly higher than is found in those which spawn near the Scottish coast, and in this respect they show a very good agreement with the group of adult herring which is present on the Scottish drift net grounds in June and July and with all those herring which occur on the Fladen Ground at maturity stages IV and V in August and September.

The results suggest rather strongly that it is on the grounds off the N. E. coast of England, and possibly even farther south where late autumn spawning herring with high K_2 also occur, that we must look for the spawning grounds of that important group of herring which is present in the north-western North Sea in June and July, and which is characterised by having the highest number of K_2 of all the autumn spawners so far examined.

V E R T. S.

Table XII.

"Race" Characters of Herring from Middle North Sea.

Date	54	55	56	57	58	59	Mean	S	Fish Exam.
		60 miles East of Tyne: Maturity VII							
Oct. 23, 1933	-	5.5	50.4	38.6	5.5	-	56.44	.06	129
		50 miles S.E. x E. of Tyne: Maturity III-V							
Sep. 10, 1936	-	3.0	54.8	38.7	3.6	-	56.43	.05	168
		40 miles E. x N. of Spurn: Maturity IV-V							
Oct. 6, 1936	0.6	2.4	53.0	41.5	2.4	-	56.43	.05	164
		70 miles E.S.E. of Tyne: Maturity IV-VII							
Oct. 15, 1936	-	2.7	46.6	43.8	6.9	-	56.55	.05	75
		35 miles East of Longstone: Maturity VI-VII							
Sep. 25, 1937	0.4	4.2	48.1	43.9	3.1	0.4	56.46	.04	265

The chronological sequence of the disappearance of these herring from the Scottish fishing grounds is not without some significance. They have generally gone beyond the range of the drifters on the more northerly grounds by the end of July, but they are frequently caught in considerable numbers on the more southerly grounds off Peterhead in August. Those which concentrate on the Fladen Ground have left that ground completely by the end of September.

Important differences were noted in Tables III and VI in the age composition of this group as represented in the samples from the drift net grounds and those caught by trawl on the Fladen. It is believed that the differences are not due to any great extent to different degrees of selection by the gear employed in their capture, but rather to a tendency towards segregation according to size of fish and depth of the water. The Fladen Ground is from 70 to 80 fm. in depth and is the deepest of the North Sea herring grounds. There has been evidence of segregation according to depth, more especially amongst North Sea autumn spawners whose spawning grounds are in comparatively shallow waters, and whose adolescence is spent in shallow coastal areas or in the shallower regions of the North Sea. It is hardly surprising therefore that the shoals of the Fladen area should contain higher proportions of the larger and older herring than those of the nearer and generally shallower drift net grounds.

K_2

Table XII.

"Race" Characters of Herring from Middle North Sea.

Date	13	14	15	16	17	18	Mean	S	Fish Exam.
		60 miles East of Tyne: Maturity VII							
Oct. 23, 1933	3.1	22.5	48.1	22.5	3.9	-	15.01	.09	129
		50 miles S.E. x E. of Tyne: Maturity III-V							
Sep. 10, 1936	2.4	20.8	45.2	26.2	3.6	1.8	15.13	.07	168
		40 miles E. x N. of Spurn: Maturity IV-V							
Oct. 6, 1936	-	23.2	39.6	31.7	4.3	1.2	15.21	.07	164
		70 miles E.S.E. of Tyne: Maturity IV-VII							
Oct. 15, 1936	2.7	16.0	48.0	29.3	4.0	-	15.16	.10	75
		35 miles East of Longstone: Maturity VI-VII							
Sep. 25, 1937	1.9	24.1	47.2	23.0	3.0	0.7	15.03	.05	265

ON UNUSUAL CATCHES OF HERRING IN THE WADDENZEE IN APRIL 1946

BY

G. P. BAERENDS

Before the closure of the Zuiderzee in May 1932 great quantities of spring herring (Zuiderzee race) used to be caught in the Zuiderzee and the Waddenzee. The catches of spring herring remained on a fairly high level from 1932 till 1936, but from 1937 onwards they dropped very considerably. While 15 million kg. were landed in 1936 the catches amounted to only 7.5 million kg. in 1937. In 1938 they dropped to 1.2 million kg. and in 1939 only slightly more than 11 thousand kg. were brought ashore. During the war the catches of spring herring were of no importance at all. It is supposed that the Zuiderzee herring stock died out because of the disappearance of its principle spawning ground, the former Zuiderzee.

However, in April 1943, as far as we know for the first time during the war, some herring were caught again in complicated standing nets, called "haringkommen", which are placed in the Waddenzee off the south-east coast of the island of Texel.

The maximum abundance of these herrings fell in the same month (April) as the maximum of the catches of Zuiderzee herring. In 1944 small amounts of herring were again caught in the "haringkommen" during April. We have no regular information on the catches in the spring of 1945 but we know of small quantities caught in April of that year. This year (1946) the catches seem to have been greater than those in the preceding years. They amounted to 551 kg. in March, 37,888 kg. in April and 87 kg. in May. The catches were still very small compared with those of the years before 1937, but they seemed to increase after 1943 and the fishermen began to hope that the Zuiderzee herring was reviving again.

To find out whether this hope was justified, we investigated a sample of 100 herrings, caught on April 30th near Texel. Unfortunately we were not able to examine samples earlier in this season and this sample happened to be the last we could get. Moreover, the sample was not representative for the whole catch. It was sorted and contained only the herrings of 20 cm. and more, whereas young herrings of 15-20 cm. were also abundant. However, the material we got gives a clear indication as to the character of these herrings.

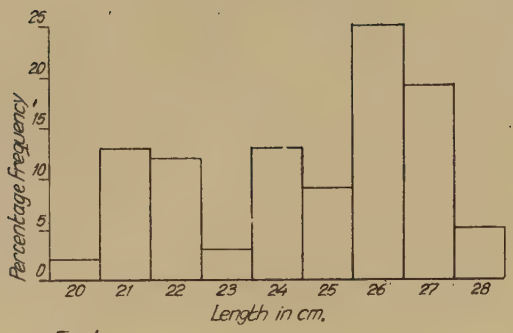


Fig. 1

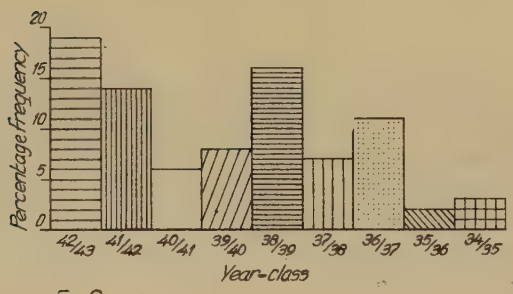


Fig. 2

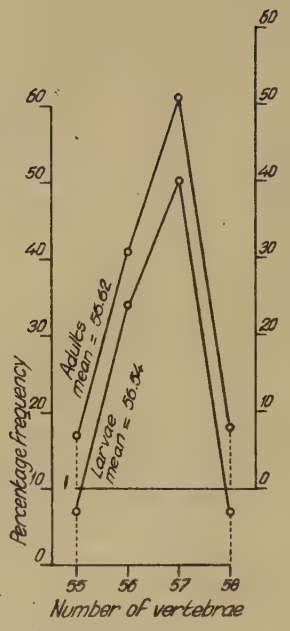


Fig. 3

In Fig. 1 the length composition of the sample is given, in Fig. 2 the age composition, and in Fig. 3 a graph of the number of vertebrae. The latter, showing a mean number of vertebrae of 56.62, immediately excludes the possibility that we should be dealing here with Zuiderzee herring (mean number of vertebrae 55.57). The graph strongly resembles that of the herring caught in the most southern part of the North Sea in winter (see TESCH, 1934, 1939). The herrings were spents or recovering spents, only 4 of the 100 individuals were full. That also excludes Zuiderzee herring. When we compare the age composition of our sample with the age composition of the herrings caught in the winter 1944/45 at the great fishery for spent herring off the Belgian coast (GILIS, 1945) we find a striking similarity in the relative strength of the year-classes. So we are inclined to believe that the herring caught in April in the Waddenzee is identical with the herring caught from December till the end of March off the Belgian coast, a result which is of some importance because - as far as we know - this herring could not be followed hitherto on its way north after having left the Belgian coast.

Of a sample of 24 herrings of lengths between 15 and 20 cm., 13 individuals had 57 vertebrae and 11 individuals 56 vertebrae. So it is likely that they belong to the same group of herring.

Simultaneously with the first appearance of the adult herrings in the last week of March, great quantities of herring larvae, measuring 20-26 mm. appeared in the Waddenzee. Fig. 4 shows the length composition of these larvae in the first and in the third week of April. Apparently they remained

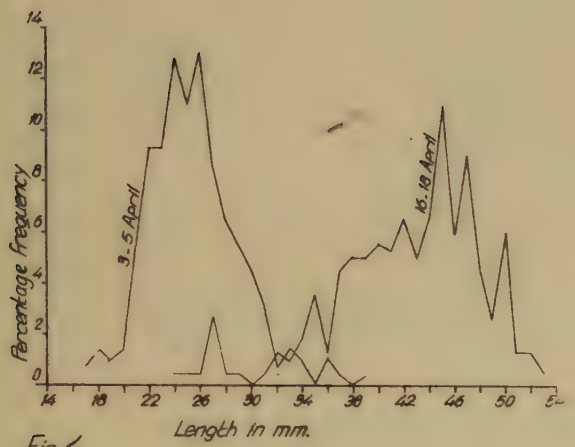


Fig.4

in the Waddenzee where in June they reached lengths of 5 to 6 cm. and became a good prey for the horse mackerel that in recent years in= vade the Waddenzee in June in great numbers.

About 150 larvae and young herr= ings of 25-50 mm. were examined for the number of vertebrae. The graph obtained closely resembles that of the adult herrings. It is likely that these larvae originated from the same schools of herring as the adult spents, penetrating with them into the Waddenzee.

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SOME REMARKS ON THE FLUCTUATIONS IN THE HERRING FISHING ON THE WEST COAST OF SWEDEN

BY

K. A. ANDERSSON

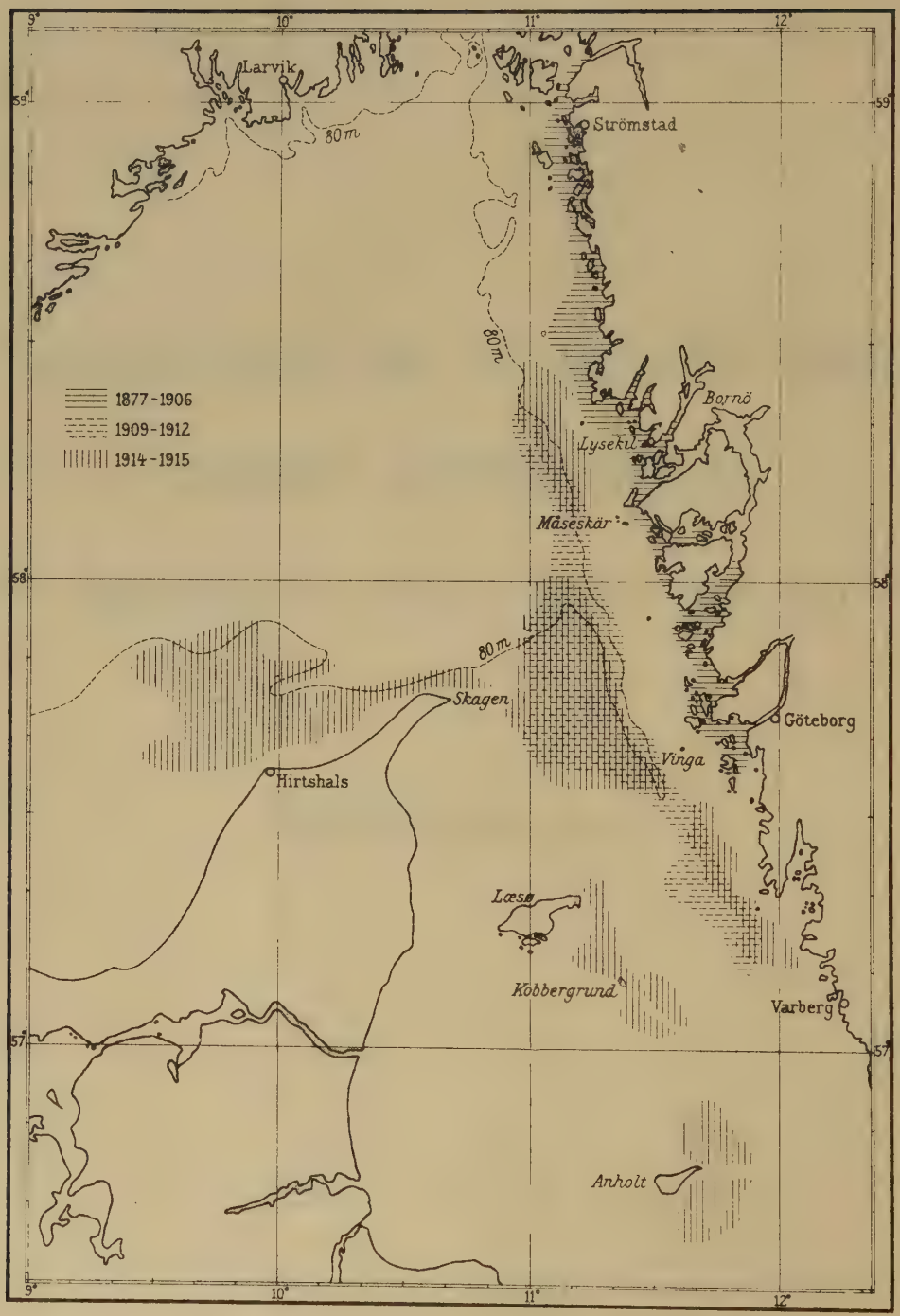


Fig. 1. Areas of Herring Fishing in the Winter Seasons; 1877-1906, with seines and nets; 1909-1912 and 1914-1915 with purse seines.

As I mentioned in the introduction to this series of addresses, herring fishing has been subject to tremendous fluctuations during the past years. The causes of this have given rise to many speculations. I cannot now deal with all the problems that arise here, far less claim to have solved the old puzzle of the Bohuslän herring fishery. I will merely attempt to throw light upon one aspect of this great and complicated subject.

First, I should like to give a very brief survey of the herring fishing at and off the west coast of Sweden during the last 50 years.

During the 1890s there was a very successful herring fishery in the Bohuslän archipelago, which at its height yielded a total catch exceeding 200,000 tons per season.

At the turn of the century and at the beginning of the new one, the herring did not penetrate into the archipelago, but remained out in the open sea. From then till the beginning of the 1920s abundant herring fishing was carried on with the purse-seine in this open water. When this fishery was at its best it gave an annual yield of 50,000-60,000 tons. In the 1920s and the 1930s the yield grew less and less, so that about 1940 it was of no importance, being only 1,000-2,000 tons per season.

In 1910, Swedish fishermen started to catch herring with the trawl in the Skagerak, and this soon became of great importance. During the 1914/1915 season the catch amounted to about 17,000 tons. It subsequently decreased greatly, yielding in 1920/1921 only about 800 tons. But later during the 1920s and 1930s, the trawl herring catches rose, and reached as much as 35,000 tons (1937/1938). But it should be noted that at this time the catches made with the trawl mainly (92-94%) consisted of small herring, usually 2 years old. But then the trawl herring fishing greatly declined until the 1942/1943 season. If we take into consideration only the full-grown herring, the Swedish herring trawling has also suffered a strong decrease from 1920 to 1943.

In the eastern Skagerak and the northern Kattegat herring is fished with drift-nets. But this fishing has also shown a strong decline from the

end of the 1920s to the beginning of the 1940s, from about 4,000 tons to 200-300 tons.

To sum up, it may be said that there has been a real revolution in the Swedish herring fishing during the last 50 years. First a period with plentiful fishing inside the fringe of skerries, then a period with plentiful fishing in the open sea (Fig.1), and now finally, a period to the beginning of the 1940s with very poor fishing everywhere in the Kattegat and Skagerak. It is only natural to ask what the cause of these great fluctuations in the occurrence of the herring in the Kattegat and Skagerak can be.

When the abundant herring fishing was being carried on with the purse-seine, the catches, in addition to a spring-spawning herring, mainly consisted of two different herring forms. One of them came as full herring into the Skagerak and the Kattegat in July and August and spawned in the Kattegat chiefly in October. This herring was characterized, among other things, by having large central areas on the scales (Fig. 2) and 56.35 vertebrae. It is usually termed the Kattegat autumn herring. The second form came to the Skagerak and the Kattegat in December as spent herring and was caught in large quantities until the end of March. This herring had small central areas (Fig.3) and approximately 56.50 vertebrae. It has been called the North Sea Bank herring. Both of these forms of herring spawn in the autumn. When the herring fishery with the purse-seine heavily declined in the 1920s and 1930s, this herring with small central areas also greatly decreased. It no longer came into the Skagerak and the Kattegat in large quantities.

But in January and February, 1944, the catches in the neighbourhood of the Skaw and off the Swedish coast became much greater than during the preceding years. When samples of the catches were analysed, it was found that a large part, about 50%, was spent herring with small central areas (Fig.4). During the 1944/1945 season this form again appeared in the catches. It began to arrive early in December, and from January to March it often constituted 50-67% of the catches. During the 1945/1946 season this form was still more abundant in the catches, forming up to 70%.

The presence of this herring with the small central areas resulted in the catches for the season showing a distinct increase and, what was still more important, the catches consisted to a much greater extent of large herring. At the beginning of April this herring, like that with large central areas, disappeared from the eastern Skagerak and to the west.

During September and the beginning of October 1945, numerous Swedish fishermen carried on considerable herring fishing with the trawl in the Fladen Ground area in the western part of the North Sea. Two samples from these catches, taken on September 5th and 20th, were examined. These were mainly full herring, and the two samples had respectively 76 and 59% of small central areas (Fig. 5), and 56.51 and 56.50 vertebrae. In the sample from September 5th none of the herring was spent, but in that from September 20th, 63% were spent. Judging from these two samples, 63% would thus have spawned already earlier than September 20th. It may be mentioned that in a catch of herring with large central areas taken in the central part of the Kattegat on October 9th, 1945, only 25% were spent. Thus, spawning takes place much

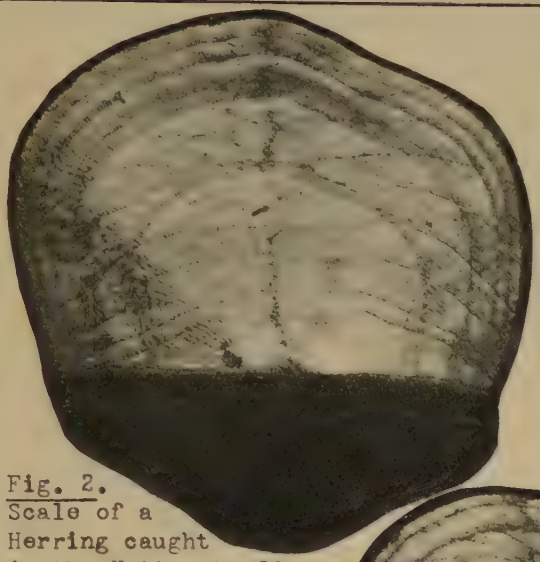
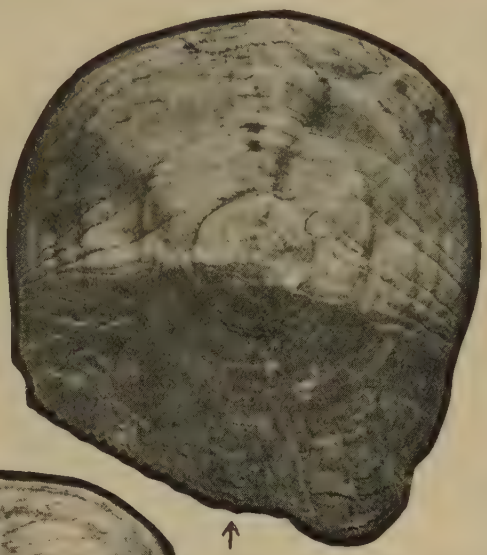


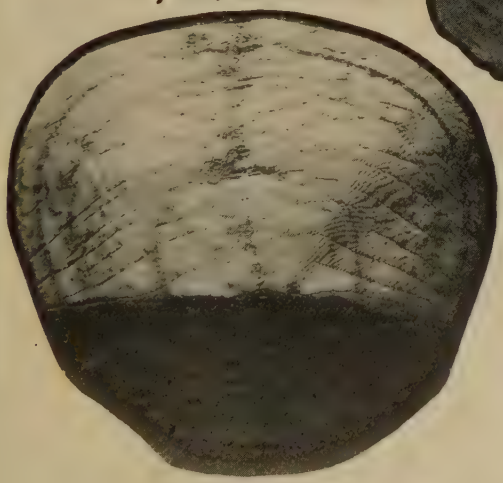
Fig. 2.
Scale of a Herring caught in the Kattegat off Varberg, on Oct. 9th, 1945, 5 years old.



3b) 6 winter rings inside the edge, hatched early in the autumn 1911.

3a) 4 winter rings inside the edge, hatched early in the autumn 1913.

Fig. 3.
Scales of Herrings caught on Feb. 19th, 1918, NE. of the Skaw.



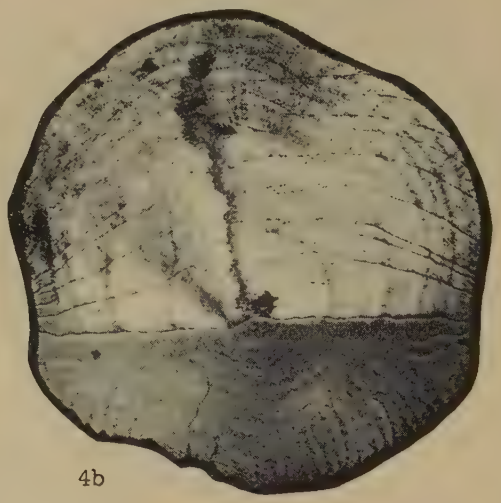
a) 3 winter rings inside the edge, hatched early in the autumn 1942.

b) 6 winter rings inside the edge, hatched early in the autumn 1939.

Fig. 5. Scales of Herrings from the Fladen Ground, Sept. 20th, 1945.

4a

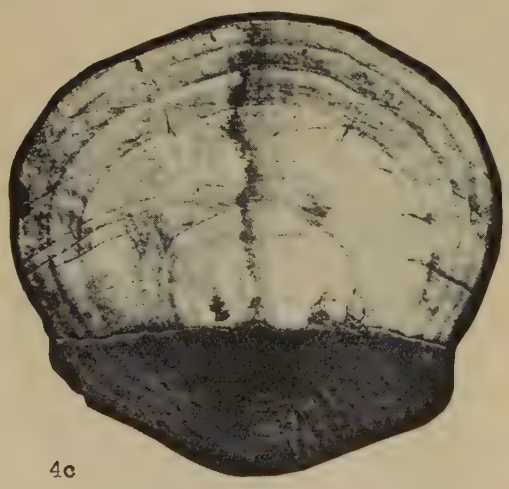
5 winter rings inside the edge,
hatched early in the autumn 1938.



4b

6 winter rings inside the edge,
hatched early in the autumn 1937.

Herring caught on January 21st between the Skaw and Måseskär Lighthouse on the Swedish west coast.



4c

4 winter rings inside the edge,
hatched early in the autumn 1939.

4d

7 winter rings inside the edge,
hatched early in the autumn 1936.

Herring caught on Feb. 4th at the northern part of the Swedish west coast,

Fig. 4. Scales of Herrings from the Skagerak, Jan. and Feb. 1944.

later in this herring than in that caught in the Fladen Ground area.

The scale illustrations (Figs.2-5) are intended to show the difference between large and small central areas. It is difficult to define exactly the difference between them, but by comparing the size of the central areas with the breadth of the immediately contiguous summer zone, it is as a rule easy enough to determine whether the central area should be counted as large or small. But, as would be expected, there are cases in which it is impossible to say whether the central area should be called large or small. The fact that the Fladen herring in question has small central areas presupposes that the scales have been laid down during the same year as the larvae hatched. Owing to the shortness of the first growth period, the scales then have small central areas.

With regard to the form which has large central areas, it must be assumed that the young herring have no time to lay down scales the same year as they hatch. The first growth period of the scale the following year is therefore long and the central area large. These two scale types agree well with the phenomenon that has been mentioned, namely, that the Fladen herring spawns earlier than the Kattegat herring.

It must nevertheless be remembered that the size of the central areas is a biological character, which may possibly vary. It must also be remembered that herring are living individuals, which, as regards a character of this kind, adapt themselves to the surrounding environment. If, therefore, the bulk of the Fladen herring, of which we are speaking, has small central areas, that does not necessarily mean that they all have. Thus, I can imagine that, if the spawning time becomes prolonged or delayed, some of the young herring will be hatched so late that they will not have time to lay down scales during the first year. That being so, a part of this Fladen herring would also have large central areas. But as long as the bulk of them have small areas, this character can be used to identify this herring population.

The use of the size of the central area has the great advantage that we can often determine, with the aid of the stage of the gonads, to which population the separate individuals belong. There is the possibility of sorting the individuals in a mixed herring sample. In any case, this is possible in the Skagerak. Support for the correctness of this sorting may be gained by counting the number of vertebrae in the usual manner.

As the herring caught in September 1945 by Swedish fishermen in the Fladen area, both in regard to scale type and number of vertebrae, agrees with a part of the herring which is taken from December to March in the eastern Skagerak, we would be justified in assuming that it is the same kind of herring, the North Sea Bank herring or the Fladen herring, that is caught in the two areas, although at different times. The connection between the two will probably be the following.

When the Fladen herring that we have been discussing here has spawned, chiefly in September, it probably disperses in different directions, but at least a part of it migrates far to the east into the Skagerak and in towards

Fig. 6. The direction of the resulting currents at ca. 30 meter's depth in the North Sea and the Skagerak. (After A.C.Johansen, 1925, Meddel. Komm. Havunders., Ser. Fiskeri, Bd. VIII, No. 8.)

the coast of Sweden. This migration can also be facilitated by the water current which from the western part of the North Sea passes into the eastern Skagerak (Fig. 6). In the spring the herring migrates from the Skagerak back to the North Sea, where it later assembles for its next spawning in September.

The Kattegat autumn herring presents an entirely different geographical migratory type. It spawns in the Kattegat mainly in October, and after spawning withdraws slowly northwards and westwards and probably migrates right out to the North Sea, whence it returns in the late summer and autumn for its next spawning in the Kattegat.

In the foregoing I have wished to show that the Fladen herring comes into the eastern Skagerak in extremely fluctuating quantities. During the 1906-1920 period it entered these waters in colossal quantities, and during the subsequent period, up to 1943, in very small quantities. During the past three winters, it has again begun to increase considerably in the eastern Skagerak.

This fluctuation in the immigration of the Bank herring into the Skagerak is clearly one of the reasons for the variations in the Swedish herring fishery.

But what causes the variation in the immigration of this Bank herring into the Skagerak? OTTO PETTERSSON and GUSTAF EKMAN believed that this variation was due to changes in the hydrographical conditions. They may possibly have been right, entirely or partially. I touched upon this problem in my introductory remarks. If it should be proved that the hydrographical conditions have not undergone such changes as could produce the variations in the migration of the herring, then the cause is probably to be sought in fluctuations in the strength of the year-classes or in the recruitment of the herring as a whole.

As a consequence of what I have said here there are some problems which ought to be investigated.

First it seems to be of great importance to investigate whether the progeny of the herring which spawn early in the autumn in the north-western part of the North Sea get scales the same year in which they are hatched, and I would very much like to propose that this be done.

In regard to the relation between the migration of herring and the hydrographical conditions I would add this to the first point of the recommendations made by the Herring Expert Meeting in October 1945, namely, that the hydrographical observations from the last 50 years should be worked up, and in fact this work has been started.

The Herring Expert Meeting held at Aberdeen in June last recommended the production of monthly charts of the herring fishing. I consider this a very important recommendation and I would propose that similar charts should be produced also for the Skagerak and the Kattegat.